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IEA OECD ETSAP news

ANNEX VIII TO EXTEND GLOBAL MODELS

ETSAP began 2002 with a new annex, a new project head, a new operating agent, and a renewed sense of purpose. Building on more than two decades of international collegiality, the new program will continue to push the envelope of systems analysis methodology to address the ever more complex problems of energy use and emissions control. Led by GianCarlo Tosato, an ETSAP veteran and international consultant, and supported by the Polytechnic Institute of Turin, Italy, Annex VIII will extend the global applications of the MARKAL family of models and the ETSAP network of energy systems analysts.

An important emerging issue is the great uncertainty attending unprecedented international economic and energy activities, such as emissions trading under the Kyoto Protocol. To address this uncertainty, ETSAP during Annex VII helped to introduce the first generation of global energy technology models. Annex VIII aims to refine these models and promote their application in the international community.

The research conducted by ETSAP during Annex VII included the development of:

- Hard-linked multi-country models to assess joint actions in international emissions trading under the Kyoto Protocol, and trade in energy commodities.
- Endogenous treatment of technological progress, or "learning curves," as an operational feature of the ETSAP models.
- Stochastic formulations that take uncertainty into greater account.

Annex VIII will continue to develop cutting-edge methodology and facilitate its widespread use. The core tool will be the now well developed TIMES model (The Integrated MARKAL-EFOM System).

"There is widespread recognition that the global challenges of climate change and other sustainable development issues call for concerted and coordinated response strategies," the Annex VIII prospectus notes. "At the same time, the notion that technological change is a key factor in shaping future economic, energy, and emission trajectories has become common wisdom.

"For example, the recent Third Assessment Report of the Intergovernmental Panel on Climate Change indicates that costs of meeting greenhouse gas stabilization targets can probably be lower with targeted technological development pathways. However, what pathways to pursue and how to foster promising developments is fraught with uncertainty. Short-term research, development and demonstration policy ('technology supply push') and market stimulation ('technology demand pull') will be required to enhance the prospects for longer-term solutions.

"The United Nations Framework Convention on Climate Change acknowledges that the global nature of climate change calls for the widest possible cooperation among all countries and their participation in effective and appropriate international responses. During Annex VII, the first steps were taken to explore the mutually linked issues of international policy measures, such as the Kyoto flexible mechanisms, and spillover of technological improvements."

Visit ETSAP on the www: http://www.ecn.nl/unit_bs/etsap/

Information on ETSAP, its activities and members is also provided on the Internet. The home page contains the latest news, general information on ETSAP, and links to: ETSAP members; ETSAP 'outreach' activities; description of the MARKAL model and its users; archives of new items; selected publications and the ETSAP Newsletter.

The aims of Annex VIII include:

- Widespread use of ETSAP tools, methodologies, data services and knowledge by the governments of the contracting parties.
- Use of ETSAP tools by other countries - OECD countries and non-member countries alike - as well as international organizations in multilateral collaboration, discussions, and negotiations.
- Use of the ETSAP tools, data services, and analytical capacity to perform scenario analysis for the IEA *Energy Technology Perspectives* project.
- Establishment of linkages with economic and environmental models and approaches that complement the work of ETSAP.
- Keeping up the ongoing ETSAP

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networks for analytical support.
- Demonstration and deployment of new methods with increased flexibility to depict complex energy systems:

1. To evaluate common or joint actions implemented with other groups of countries, including emission trading or trade in energy commodities.
2. To treat evolution in the costs of new technologies endogenously, including spillover effects of international collaboration.
3. To deal explicitly with planning under uncertainty.

The ETSAP tools are available not only in most OECD countries, but in many other countries in Eastern Europe and the developing world. Alternative proposals for differentiated national targets have already been evaluated with respect to cost-effectiveness and equity indicators. ETSAP has the capability to estimate the cost savings of common actions by a wider group of nations. This may be either within the industrialized world or developing countries, or between them as provided by the Clean Development Mechanism of the Kyoto Protocol.

ETSAP provides powerful support to the users of its methodologies and tools. It has established, and continues to nurture, an international network of expert analysts who cooperate in developing technologically informed options and in calculating the cost of restricting emissions of pollutants. The family of ETSAP models uses consistent formulations and data on technologies. The ability to calculate marginal costs of increasingly stringent reductions in emissions makes it possible to identify distributions of agreed levels of emissions among countries that minimize total costs.

Tosato Heads ETSAP Annex VIII

GianCarlo Tosato, who has represented Italy on the Energy Technology Systems Analysis Program since 1978, will serve as project head in Annex VIII. With wide experience in international energy analysis, he will be well prepared to lead ETSAP's continuing development and application of global energy models.

Dr. Tosato has been engaged in energy systems analysis for nearly thirty years in private companies and public organizations. He was among the group that originally developed the MARKAL model and its databases from 1978 to 1982. Then, he was mainly responsible for the technological characterization of hundreds of existing and projected energy supply and demand technologies. In recent years, he has served as vice chairman of the ETSAP executive committee.

Since 1994, Tosato has been with ENEA, the Italian National Organization for New Technologies, Energy and Environment. At ENEA, he was leader of the "post-Kyoto technical unit," a group of up to 30 experts that supports the Italian Public Administration and other organizations in complying with the Kyoto Protocol. He headed the unit at the energy department of ENEA on technology analysis, models and strategic evaluation. For the International Energy Agency, in addition to his ETSAP work he provided technical support to the Italian representative to the IEA long-term planning unit, and to the Advanced Local Energy Planning Project of the IEA implementing agreement on energy conservation and community systems.

On leave from ENEA in 2001, he was a consultant to the U.S. Energy Information Administration in developing a multiregional world technology model and in evaluating the cost of international mitigation options. He is presently responsible for socioeconomic studies of the European Fusion Development Agreement, working in the Close Support Unit of Garching (Munich, Germany), hosted by the Institut fuer Plasma Physik of the Max Planck Gesellschaft. There, he does long-term energy modeling, and coordinates studies carried out by European Euratom Associate Institutes in fields such as the direct cost of fusion.

Around the world

Australia

The Australian firms SMEC and Intelligent Energy Systems, in association with the Australian Bureau of Agricultural and Resource Economics (ABARE), have been selected to manage an Energy Policy and Systems Analysis Project involving five countries in Southeast Asia. The project will use MARKAL as its primary analytical tool. The project is funded by AusAID, the government body charged with overseeing Australia's foreign aid program. It is planned to extend over 3.5 years. The project aims to strengthen the institutional capability of the five ASEAN countries in carrying out energy policy analysis.

The five countries concerned are Indonesia, Malaysia, Philippines, Thailand and Vietnam. Indonesia and Philippines have existing MARKAL models that may need updating. While some preliminary work on MARKAL models for the other three countries has previously been undertaken, considerable further development is required.

The major project aims are threefold:
- To install PC hardware and MARKAL software and develop operational databases in each country.

- To train personnel in use of the model and interpretation of results.
- To undertake policy analysis studies relevant to each country.

The project will also have a regional component in that the national MARKAL models will be later combined into an ASEAN regional model to study issues relevant to the region as a whole, such as electricity and gas interconnections and greenhouse emission abatement strategies.

Formal structures for the project include a national coordinating committee in each country as well as an overall project coordinating committee. An ASEAN Australian MARKAL Regional User's Group (AAMRUG) will be established to provide a forum for interchange of ideas and study results for project participants. The project team looks forward to interaction with ETSAP activities where possible, and it is especially interested in exchanging ideas with any MARKAL outreach programs tackling similar issues.

ABARE is continuing to maintain the Australian MARKAL model and to use it for policy analysis in a range of areas. Following major revision to its regionalized electricity supply sector, articles and reports have explored topics such as:

- Consequences of electricity sector liberalization for investment decisions, especially as regards choices between coal and natural gas-fired combined-cycle gas turbines, and the role of refurbishment of existing coal-fired capacity
- Renewable sources of electricity, and the implication of the government's introduction of a system of tradable permits

Other topics currently being researched include:

- Analysis of policies in support of biofuels such as fuel ethanol - which already benefits from a full excise exemption - utilizing MARKAL's capability of reflecting energy taxes and subsidies
- Revisiting policies of energy efficiency in energy end-use, making use of MARKAL's technology-specific hurdle rates.

Funded by the US Energy Information Administration (EIA), ABARE has recently completed major enhancements to the ANSWER software, leading to version 5. The most important aspect of version 5 of ANSWER is that it allows a single database to hold data for multiple regions, and provides the user with the capability to carry out a multiregion MARKAL run, incorporating bilateral or global trade between regions, almost as easily as a single-region run.
Version 5 of ANSWER is currently under beta test at the US EIA. It is expected to be officially released at the May ETSAP Meeting being hosted by ABARE in Canberra from 27-31 May 2002.

Belgium

In Belgium, the Vlaamse Instelling voor Technologisch Onderzoek (VITO) completed a study of the potential for reducing pollutants from generating electricity. Its aim was to make a detailed analysis of the possibilities and costs to reduce nitrogen oxides, sulfur dioxide, particulate matter, and heavy metals by 2010. The study is supported by the government to prepare Belgium to fulfil the requirements of the Göteborg Protocol on acidification and tropospheric ozone. Belgian electricity producers and governmental authorities participated in the steering committee.

A very detailed MARKAL model of the Belgian electricity sector was built that includes individual plants with different retrofit options. To estimate unabated emissions in 2010, several scenarios were assumed: a reference scenario, a high gas price scenario, a green scenario, a demand-side-management scenario, and a Kyoto scenario. Cost reduction functions for individual pollutants were derived, starting from the unabated emission levels of these scenarios. The shadow prices on pollutant constraints show the marginal abatement costs. On average, the derivation of one cost curve required almost 200 MARKAL runs.

Finally, a joint abatement strategy was analyzed. In some cases, a joint strategy was found to provide some cost savings, but not when the emission limits were not very stringent.

Canada

In Canada, the National Climate Change Implementation Process entered a new phase in 2001. Richard Loulou and Amit Kanudia and their team were again retained by the Canadian government as one of two micro-modelers, with the objective of simulating several strategies to achieve the greenhouse gas emission reductions defined under the Kyoto Protocol. These strategies include targeted sectoral measures, as well as several permit trading schemes, as follows:

- Broad-as-practical permit coverage with full auctioning of permits.
- Coverage of large final emitters with several alternate permit allocations, including gratis grandfathered allocation, allocation proportional to output, and allocation following a triptych formula that accounted for regional differentiation.

All simulations were made using two alternate prices for international permits. A special constrained run was made to simulate the imposition of a supplementarity clause according to which no more than 50% of the reductions would be made through permit purchases.

The simulations of the several output-based allocations proved particularly interesting in that they showed profound differences from fixed allocations. Output-based allocations attempt, and largely succeed, in alleviating the negative effects of greenhouse gas policies on industrial output and on industrial competitiveness.

In order to simulate the output-based allocations, the MARKAL equations were modified in such a way that the act of allocating a unit of permits to a sector had an impact on the marginal cost (i.e., the price) of any commodity produced by that sector. This modification may be applied to other similar situations. In addition, the 8-region North American model was further disaggregated into a 14-region model, where each Canadian province or territory is now separately modeled with its own database.

Loulou and Kanudia are collaborating with researchers at the International Institute for Sustainable Development, Winnipeg, Canada, on an application of the Canadian MARKAL model where demand segments are disaggregated by income group. The model will be used to assess energy policies and measures whose 'uptake' is sensitive to income. In particular, each income group exhibits a different price elasticity of end-use demand for energy services.

In international work, the Canadian group has been awarded contracts by the International Energy Agency (IEA) for the construction and operation of a World 15-region TIMES model. The model will emphasize technology analysis and technology learning for the IEA *Energy Technology Perspectives* project. The initial version was completed in February 2002, and the models are currently being sent for review by experts. On this project, they are interacting with the ETSAP Operating Agent, as well as IEA and researchers at the Energy research Centre of the Netherlands. The group is continuing its participation in the construction of the 15-region MARKAL world model called SAGE at the Energy Information Administration of the U.S. Department of Energy.

Under the supervision of Loulou and Kanudia, two PhD students at Montreal universities are working on issues of equity and of rivalry in the climate change domain. Kathleen Vaillancourt studies equitable burden sharing based on multi-agent, multi-objective decision making approaches. Maryse Labriet studies joint reduction of greenhouse gas emissions based on non-cooperative game theory. Both students have participated in the construction of the global MARKAL/TIMES model, and will use it for their thesis work.

Finland

The Technical Research Centre of Finland (VTT) has used its EFOM/ENV-model and its partial equilibrium model of the Finnish national economy in a number of policy studies for the Ministry of Trade and Industry. These studies were carried out in cooperation with the Government Institute for Economic Research, and with the private Research Institute of the Finnish Economy. The results have been reported in detail to the Government Working Group for the Kyoto Agreement, consisting of five members of the Government of Finland.

In cooperation with the Helsinki University of Technology, VTT started the construction of a Finnish TIMES model in 2001. Modules representing the energy production sectors have been completed. VTT has also started to develop a working solution to the data management problem, a user's interface.

Germany

In Germany, research at the Institute of Energy Economics and the Rational Use of Energy (IER) at the University of Stuttgart focuses on three activities. The first is assessment of existing and new technologies in the power supply sector. The second is the development of methods and tools to study complex systems on different levels of detail with respect to time and geographical resolution. The third is technological and macroeconomic analysis of energy systems to answer energy related questions such as climate change protection strategies and the consequences of liberalization of energy markets.

The third model experiment (MEX III) of the Forum for Energy Models and Energy Economic Analysis (FEES), which is intended to be an open communication platform for energy modelers and analysts in Germany, is coordinated by IER. MEX III has studied environmental and climate protection policies in liberalized energy markets with a focus on the future role of renewables. To better address the different aspects of this topic, soft links between the different models of the participants have been established, e.g., linking an input-output model with a bottom-up model. Methodological aspects of the linkage of bottom-up and top-down models were discussed at a workshop in Bonn. The essential results of MEX III were presented at a final workshop at the Federal Ministry of Economics and Technology in March this year.

In cooperation with the Akademie fuer Technikfolgenabschaetzung in Baden-Württemberg, IER coordinated the "Energy Discourse Bavaria" of the Bavarian Ministry of Economic Affairs, Transport and Technology. Within this forum, stakeholders from policy, industry and public groups discussed different aspects of the future energy policy of Bavaria. As part of this dialogue IER has presented scenarios on climate change protection measures and the future role of nuclear energy for Bavaria. For this purpose IER has developed a TIMES model of the Bavarian energy system.

Together with the Spain's Institute for Perspective Technological Studies of the Joint Research Center of the European Union, IER is coordinator of the ACROPOLIS project of the European Union. ACROPOLIS addresses policy questions in reducing greenhouse gas emissions on the global and country levels. Key elements of the project are four case studies. These analyze the role of energy supply policies related to renewable portfolios and tradable green certificates, the impact of internalization of social and environmental external costs, the effects of a policy of energy efficiency standards on the end-use side, and the impact of

international flexibility mechanisms. The project consortium consists of 13 modeling groups with 15 models (4 country models, 4 regional models and 7 world models). IER is also participating in this project with a TIMES model of the German energy system. Results of the baseline scenario and of the case study on renewable portfolios were presented and discussed by the project partners at a workshop in Seville, Spain, in February this year.

For the Enquete Commission of the Federal Parliament, the German TIMES model is also being applied in an ongoing study of sustainable energy supply under the conditions of globalization and liberalization. The scenario analyses carried out by IER focus on the impacts of greenhouse gas abatement policies, the future role of combined heat and power in Germany, and the achievement of renewable energy targets for a time horizon of 2050.

Greece

During the past two years, the Centre for Renewable Energy Sources in Greece has developed a detailed model of the Greek energy system using MARKAL. The supply side of the energy system has been modeled in detail, including the interconnected electricity network and the non-interconnected electricity network of the islands. The refineries are included as an aggregate (the four existing refineries are modeled as one), with the existing capacities per technology. Natural gas was introduced in 1997 in Greece. In order to model its penetration, one needs to consider the development of the distribution network, which is still under construction, and possible expansions planned by the Public Gas Company.

On the demand side, the major energy consuming industries of cement, steel, aluminum and ammonia production have been modeled in detail. The remaining industry has been differentiated into two categories - large and small - and modeled accordingly. Household consumption has been analyzed using the different type of housing that exists in Greece with all the possible end-use demand categories. Statistical data from surveys performed in recent years were used for the current level of consumption per end use. The transport sector has been modeled in detail, keeping in mind the existing technologies. The forecast of useful energy demand was based on extended consultation with experts of the Greek energy sector, including the Public Power Corporation and the Public Gas Company.

A number of alternative scenarios have been developed using three different oil price scenarios, according to forecasts of international oil prices by the U.S. Department of Energy, and two different scenarios for the introduction of natural gas in the energy system. These are an optimistic scenario and a conservative scenario depending on the construction of the gas distribution network and the acceptance of end users. Finally, the Kyoto protocol targets have been used in order to assess the available options for the Greek energy system.

The model is still being refined and updated, as newer statistical data become available. The results of the most interesting scenarios have been presented to the Greek Ministry for Development, for consultation.

Italy

In the Basilicata region of Italy, the methodology for advanced local energy planning developed in the framework of the International Energy Agency Annex 33, “ALEP - Advanced Local Energy Planning,” is being applied. The methodology uses RMARKAL, the regionalized version of the model, as a comprehensive tool. A first optimization study dealt with Potenza, the chief town of Basilicata region. The Bucaletto district, which has risen in the town outskirts since the 1980 earthquake, is now the scene of a recovery project. A careful evaluation of its new role was needed within the framework of the Municipal Energy Environmental Plan.

Therefore, a two-region modeling approach was used to analyze in depth the energy systems involved. The trade of electricity and heat between the two regions was evaluated, considering a district heating system for the Bucaletto district. The model calculated the possible contributions of the residential, services and commercial sectors to reductions in local and global pollutants, including carbon monoxide, nitrogen oxides, sulfur oxides, total suspended particulates, and carbon dioxide.

A second study was made of the Agri Valley, a sub-region consisting of about thirty villages. This area is of interest because of a recent increase in mining activities, following the discovery of a very large crude oil deposit, and the presence of a national park. In this case a one-region approach was used to model the local energy system and the waste management sector, investigating the supply side as well as the features of the demand sectors. Three scenarios with carbon dioxide emissions constrained pointed out the technological changes that would be required, such as additional insulation in buildings, and the related environmental costs. In both case studies, the results show the contribution of renewable energy technologies, such as biomass plants, wind power plants, mini hydro plants, solar heating and photovoltaic systems, and of energy saving options at the domestic level.

The Italian participants in the IEA Annex 33 project, with the financial support of the Italian Agency for New Technologies, Energy and the Environment (ENEA), have prepared an Italian version of the ALEP Guidebook, *Guida alla Pianificazione Energetico Ambientale a Scale Locale*, which is now ready for printing. A new Web site (www.iea-alep.pz.cnr.it) will also offer local energy planning information in Italian and English.

The research group at the Institute of Methodologies for Environmental Analysis consists of Vincenzo Cuomo and Maria Macchiato (co-ordinators), Carmelina Cosmi, Gerardo Marmo, Filomena Pietrapertosa and Monica Salvia. Stakeholders in the research are the National Research Council, the National Institute for the Physics of Matter, and the local authority in the Basilicata region.

Japan

In Japan, the Research Group for Energy System Assessment, headed by Osamu Sato, is in charge of ETSAP at the Japan Atomic Energy Research Institute (JAERI). The work of this group is divided into two research categories: analysis of Japan's energy systems with particular focus on the role of nuclear energy, and nuclear fuel cycle systems analysis for considering long-term nuclear energy development strategies and the role of new reactor types in Japan.

In the field of energy systems analysis, a macroeconomic model has been developed in order to study the economic impacts of a possible nuclear phase-out in Japan. The first stage of the development has finished, and an analysis has been made with an integrated MARKAL and macroeconomic model. Relevant to the research subject of ETSAP Annex VII, historical data on the price of solar photovoltaic systems have been collected and analyzed by Masanori Yamaguchi, a temporary staff member from Hitachi Research Laboratory. The results are being summarized now. In order to make an assessment of nuclear energy in broader perspectives, the basic information on technology risks is being collected and compiled by Katsuhiko Kunii.

In the field of nuclear fuel cycle systems analysis, Kenji Tatematsu, and Yoji Tanaka, a temporary staff member from Mitsubishi Heavy Industries, Ltd., are engaged in the assessment of advanced nuclear systems with reduced moderation water reactors (RMWRs), water-cooled breeder reactors being developed by JAERI. Although RMWRs have rather low breeding ratios, it was found that they would possibly be a realistic alternative to sodium-cooled fast breeder reactors by controlling the ultimate amount of natural uranium consumption at a certain allowable level.

Korea

ETSAP activities in Korea are under the direction of Heesung Shin of the Korea Institute of Energy Research (KIER), with Jongchul Hong as the principal modeler. Since MARKAL was introduced in Korea, it has been used for energy technology and systems analysis especially in the iron and steel industry. MARKAL has also been used to estimate the potential for reducing carbon dioxide emissions in many sectors in several different scenarios. With funding by the Korean governments, the technology database is now being updated at KIER with the cooperation of other organizations. Using this database, MARKAL and TIMES are expected to play an important role in Korea in the development of energy technology policy related to climate change issues.

The Netherlands

The Energy research Centre of the Netherlands (ECN) recently finished the SAPIENT project, sponsored by the European Union. The concept of 'clusters of technologies' which is needed to deal with interdependent learning between technologies, was dealt with in detail in SAPIENT. A 'cluster of technologies' is defined as a group of technologies sharing a common essential component. This component is selected as the learning component in each of the technologies in the cluster. Examples of clusters of technologies are gas turbines, fuel cells, photovoltaic (PV) modules, wind turbines, steam turbines, and boilers. Existing learning technologies in the model's database need to be grouped into clusters. Ten clusters of learning technologies were implemented, representing in total sixty technologies. It became apparent in the SAPIENT project that inclusion of more conventional technologies in a learning cluster, such as steam turbines, can effectively lock out such technologies as solar PV and fuel cells.

ECN also performed a study of the effects of 'grandfathering' carbon dioxide emissions. The study analyzed the potential capital transfers among economic sectors that would result in Western Europe over the period 1990 to 2030. Four different policy variants of grandfathering were examined. These distinguished between cases covering all economic sectors in Western Europe or only those sectors exposed, and a flat-rate system based on past emissions or a proportional system based on projected future emissions.

The study used a partial equilibrium model, MARKAL-MATTER3.0 Elastic Demand. This bottom-up optimization model estimates trends in sectoral emissions for both baseline and mitigation scenarios. It generates marginal abatement curves at the sector level of Western Europe, based on a large, comprehensive set of production abatement options covering both materials and energy flows. It accounts for price-induced changes in final demand. It estimates the most efficient allocation of sectoral emissions under different policy constraints and, hence, it analyzes potential emissions trading and capital transfers, given a certain initial allocation of carbon dioxide allowances. Finally, it assesses the abatement costs of different policy options of grandfathering carbon dioxide allowances.

Currently, ECN is participating in the ACROPOLIS study, which includes a number of modeling teams from the European Union as well as the USA and Japan. Common scenarios are evaluated. A harmonized reference case was established, and the first scenario case has been completed. The first scenario case looked into the effects of a target path for sustainable electricity production and the possibilities of trade of green certificates.

Sweden

ETSAP activities in Sweden are conducted at the Department of Energy Conversion, Chalmers University of Technology, headed by Erik Ahlgren. These currently include risks and benefits from a trans-Nordic gas grid, tradable green certificates, and the extension of the Nordic energy market.

Positive and negative effects of investing in a trans-Nordic transmission grid for natural gas are being evaluated. Optimal planning strategies are compared to those given exogenously. The results so far indicate that potential benefits from the gas grid under future carbon dioxide constraints are of the same magnitude as potential losses may be if gas prices differ sufficiently from those assumed in the design of the gas grid.

The analysis of a system for green certificates compares a common Nordic market with a system in which all four Nordic countries initiate their own markets. The quotas for each country correspond to the European Union directives. The consequences to the certificate market if emission-permits trading is launched simultaneously are also under investigation.

Analysis of how increasing trade between the northern Continental Europe and the Nordic countries will affect the long-term development of Nordic energy system is carried out. The Focus is mainly on grid-distributed energy systems. The Kyoto flexible mechanisms "joint implementation" and "emission trading" will be included in the study. Different ways of modeling the extension bringing only parts of the countries' energy systems into the model will be analyzed and tested.

Switzerland

In Switzerland, the Energy Economics Modeling Group of Paul Scherrer Institute (PSI), led by Socrates Kypreos, performs work related to ETSAP. As technological change is a key factor in shaping future economic, energy and emission trajectories, PSI participates in ETSAP to help develop the tools needed by countries to identify measures to comply with their obligations while meeting economic and social aspirations. The aim of the modeling group is to develop and implement state-of-the-art-modeling approaches to assess sustainability issues on the national, regional, and international levels by collaborating with advanced modeling teams in Switzerland and abroad. Recent work has focused on the development and application of global energy models that feature endogenous technological learning and trade in energy and carbon dioxide emissions.

As a participant in the SAPIENT (Systems Analysis for Progress and Innovation in Energy Technologies) project of the European Union (EU), PSI's main objective was the development of compact and integrated models, namely the optimal growth energy system optimization model MERGE-ETL and the multiregional electricity optimization model ERIS-2FLC. These models include learning by doing and learning by searching as well as an R&D portfolio submodel to define optimal allocation of public R&D spending under uncertainty. SAPIENT integrates the results of large-scale models into the ISPA (Integrated System for Priority Assessment) meta-model. Based on the findings of the large-scale models, the role of ISPA would be to explore the domain of optimal R&D strategies with multiple objectives under uncertainty, i.e., incorporating notions of hedging.

The ACROPOLIS (Assessing Climate Response Options: Policy Simulations) project involves the European Commission, the International Energy Agency, and ten national groups. The project addresses the general objectives of the EU's Fifth Framework Program for Energy and aims at applying and comparing existing models to assess the impact of energy technologies and policy measures on greenhouse gas emissions and on sustainability in a global systems analysis perspective. PSI addresses the impact of regulatory policy on the supply side, specifically the renewable portfolio, tradable green certificates, and international flexibility mechanisms to mitigate climate change.

Using the Global MARKAL-MACRO model, PSI concluded that concentrated efforts will be needed to support research, development and demonstration of renewables to help them progress down their learning curves. Under ideal policy conditions, the discounted cumulative system costs of a massive introduction of renewables would increase energy system costs by about one percent. Otherwise, fossils systems will lock out renewables in the short term. Forcing in renewables later would increase the cost by about five percent. Only market-oriented policies, which favor the trade of green certificates across all world regions, will lead to the most efficient installation of renewable systems.

In further work, PSI is participating with the Universities of Bern and Geneva to establish an integrated assessment model and its database that explicitly takes into account uncertainty in order to assess the impact of climate variability on economic activities and the environment. Led by Olivier Bahn, PSI is working with six other national groups to advance the GEM-E3 general equilibrium model. The role of PSI is to link GEM-E3 Switzerland with the European version of the model, and then to perform policy analyses with this new extended model.

USA

In the spring of 2002, the Office of Energy Efficiency and Renewable Energy (EERE) of the United States Department of Energy completed a study in preparation for US DOE's Strategic Planning. The study was based on the results of the US MARKAL-MACRO model generated at Brookhaven National Laboratory (BNL), where John Lee is the principal investigator. Phillip Tseng of US DOE is the overall project manager who coordinated the input from various stakeholders and guided the direction of the study. The main focus of the study is on the evaluation of cost and benefits (economic, environmental and security) of the EERE R&D portfolio that consists of individual technologies covered in current US DOE's R&D activities.

ECN Policy Studies

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In April 2002, Phillip Tseng sponsored a MARKAL model workshop in Washington DC to demonstrate the viability of the model for integrating the analysis of individual technologies under the Government Performance & Results Act (GPRA). Ann Reisman and John Lee of BNL organized the workshop, with Gary Goldstein of IRG and Richard Loulou of McGill University as invited speakers. Many DOE technology project managers and consultants for GPRA analysis were among the workshop participants.

Under a bilateral technical assistance agreement between United States Environmental Protection Agency and Taiwan Environmental Protection Administration, John Lee is coordinating an international conference on MARKAL modeling and Clean Development Mechanism (CDM) project outlook in Central America. The conference is expected to take place at San Juan, Puerto Rico, in early October 2002. Jentai Yang of US EPA Office of International Affairs is the general manager of the bilateral agreement. In addition to hosts from U.S. and Taiwan, the conference invitees will consist of MARKAL modelers and CDM office directors of the seven Central American governments.

The Energy Information Administration (EIA) is engaged in a major enhancement and reformulation of MARKAL to support their midrange international energy forecasting needs. The new variant of MARKAL, named SAGE (System to Analyze Global Energy), is a multiregional model of world energy use and trade. The model is to be expanded in scope to enable it to handle international trade, to run in more of a simulation than an optimization mode, to smooth market allocation behavior, and to include technological learning curves. Once fully operational, the modeling framework will be used for the annual publication EIA *International Energy Outlook*, beginning with the 2003 edition. In 2001, GianCarlo Tosato spent several months advising EIA analysts of modeling energy systems with MARKAL.

ETSAP Chair Phillip Tseng, Vice Chair GianCarlo Tosato, and Project Head Koen Smekens attended an International Energy Agency (IEA) Zero Emissions Technology Strategy (ZETS) planning workshop on March 19 and 20, 2002, in Washington, DC. Carmen Difiglio of IEA and Tosato provided a status report of the MARKAL/TIMES model. Tseng gave an overview of ETSAP activities. Smekens presented some model results using the MARKAL model of the European Union. The presentations generated many questions. Tseng reported that there is strong interest in future collaboration between the IEA Implementing Agreements for the ZETS project and the IEA *Energy Technology Perspectives* project.